Human Factors of Lessons Learned Programs

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Why Human Factors?

- LL programs used by and for humans
- Therefore understanding human behavior / importance will help design better systems
- Many HF aspects important: interface design, socio-technical systems design, usability.
- This paper concentrates on cognitive aspects of using LL systems
- Example from aviation maintenance incident analysis

Where do LL's Come From?

- Positive Events:
  - Successes, solutions, designed experiments, literature, …
  - Try to replicate them
- Negative Events:
  - Accidents, incidents, field failures, user feedback
  - Try to avoid them
- Data comes from Sender to Receiver

But….

- Not all potential Senders send LL items
- Not all potential Recipients receive and act on the LL
- …for a variety of reasons

Curse of Dimensionality

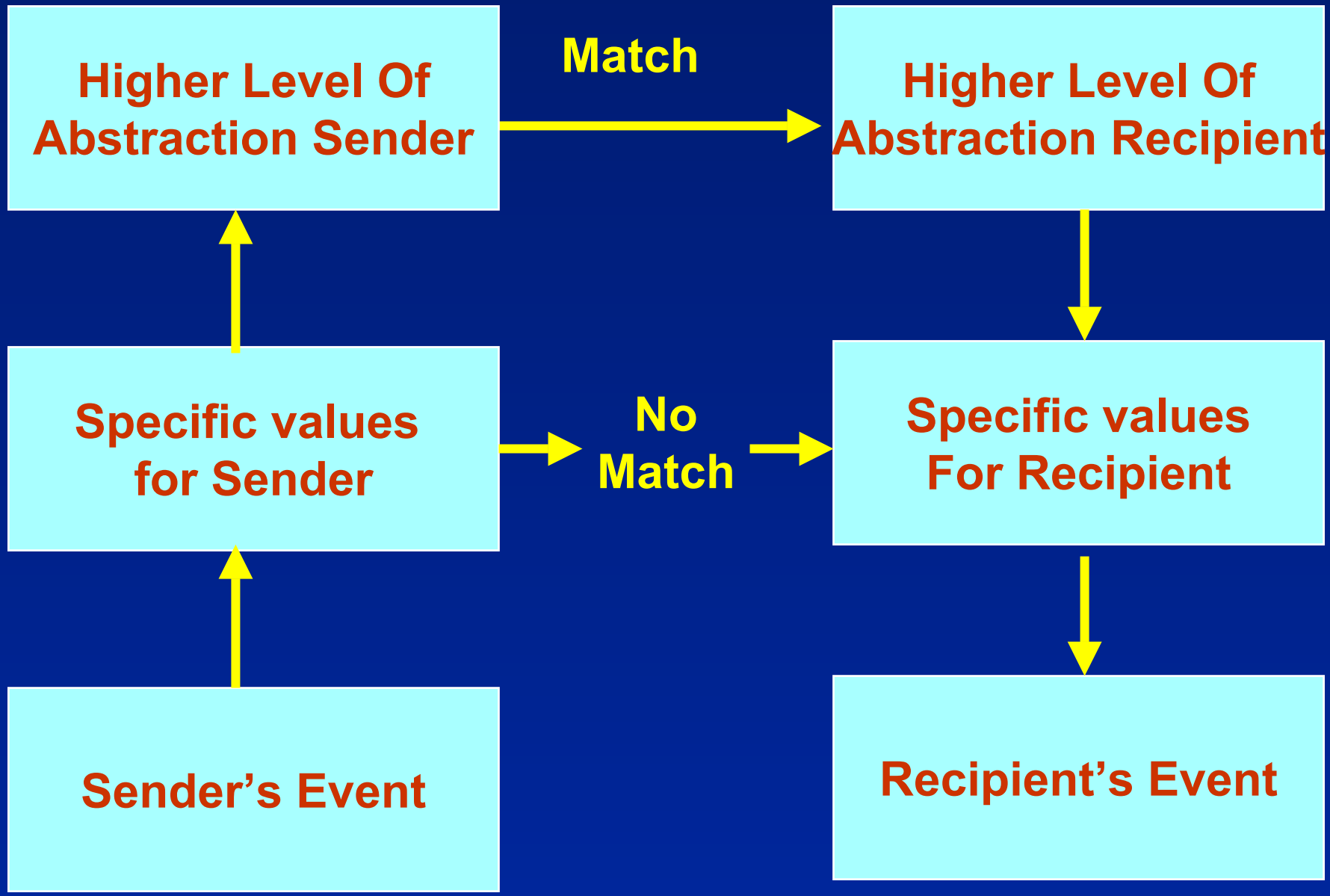
- Events are complex, many factors affect each event and its success / failure. E.g operator did not follow procedures, poor equipment design, poor training
- Do **all factors** have to match the recipient's situation for a LL to be a match?
- The question is rather: **How closely do factors need to match to find an appropriate LL?**

Curse of Specificity

- IF recipient is
  - (a) overworked on other things
  - (b) overwhelmed with LL's
- THEN a perceived "poor match" is a quick way to dismiss the extra work of thinking through the applicability to recipient's need
- Can HF do anything about this?
- Yes, see John Voit's work on models of LL systems and how they operate

Is Abstraction a Key?

- Although the chance of a LL matching the needs of the recipient for all factors is remote, matches can still be found at a more aggregated level of abstraction
- Actual values of factors would be a zero level of abstraction
- People are known to be very good at moving between levels of abstraction, even though this is cognitively demanding.
- "Abstraction Hierarchy" well known in HF


Higher Level Of Abstraction Sender
Match
Higher Level Of Abstraction Recipient
Specific values for Sender
No Match
Specific values For Recipient
Sender's Event
Recipient's Event

But…

- Recipient must be able to move to the higher level of abstraction
- Sender must be aware that recipient may only find match at higher level of abstraction
- System designers/champions must design the system to facilitate such transition

Example: Incident Investigation

- In aviation Maintenance, we may have "dealt with" each incident, but what next?
- Accumulate much data over time period
- Mine the data for free advice!
- We currently do some of this:
  - Counts and costs by managerial unit
  - Counts and costs by outcome type
- Usually Pareto charts / counts
- Only a one-dimensional look at the data

Does 1-D Look Help Control?

- Accumulated data for August 2004:
  - Hangar 2: 7 incidents, cost = $174,000
  - Hangar 5: 2 incidents, cost = $120,000

- SO WHAT????
- What do we say to managers?
  - Hangar 2: “Must try harder”
  - Hangar 5: “Don’t get complacent”
- But HOW can managers respond?

Outcome Pareto Data

Error Classification	Total
Improper installation	58
Improper servicing	5
Improper/incomplete repair	6
Improper fault isolation/ inspection/testing	25
FOD	13
Equipment damage	13
Injury	54
Other	30
Total	205

Again, SO WHAT?

Deriving Effective Control

- To control, we need to know how our actions affect the outcome
- These must be specific actions:
  - Improve maintenance of work stands
  - Make documentation easier to read
  - Don't do steps not on procedure, even if that is the norm here
- …rather than: "Try harder"
- Need to relate specific causes and effects
- Need to USE our accumulated data

Data Analysis Example

- 206 valid incidents in data base
- New analysis here was to examine data statistically for event patterns:
  - **Error type:** how error manifests itself finally
  - **Contributing Factor:** Causal factor
- Used **Cross-Tabulation** of error types **and** causal factors
- Use **patterns** to find effective strategies

Finding Patterns

- Are particular Contributing Factors related to particular **Error Types**?
- Used Chi-square analysis of tables relating Contributing Factors to Error Types
- If significant, find which cells have more events than expected by chance
- Started at top level of abstraction where there is plenty of data available
- Example for "**Information**" Contributing Factor:

Error Classification	Information Not a Factor	Information A Factor	Total
Improper installation	21	**36**	58
Improper servicing	4	2	5
Improper/incomplete repair	2	5	6
Improper fault isolation/ inspection/testing	12	13	25
FOD	5	8	13
Equipment damage	5	6	13
Injury	**49**	5	54
Other	13	16	30
Total	112	94	205

Results: **-Improper Installation over represented**
-Injury under represented

Error Patterns Overall

- For each error type we can find those contributing factors significantly over- and under-represented
- These give most and least effective potential interventions
- If relationship not significant, then a contributing factor is equally effective (or ineffective) across error types
- This leads directly to management action
- Summary Table:

Error Classification	Causal Factors	
	Over-Represented (most effective interventions)	**Under-Represented (least effective intervention)**
Improper installation	1. Information 2. Supervision	---
Improper servicing	4. Job/task 8. Organizational issues	---
Improper/incomplete repair	8. Organizational issues	---
Improper fault isolation/ inspection/testing	5. Individual performance 6. Environment/ facilities 8. Organizational issues 9. Supervision	---
FOD	6. Environment/ facilities	4. Job/task
Equipment damage	---	4. Job/task 8. Organizational issues
Injury	---	1. Information 6. Environment/ facilities
Other		5. Individual performance 6. Environment/ facilities 8. Organizational issues 9. Supervision

How Does This Help?

- Causal Factors imply specific interventions:
  - Knowledge / Skills implies Training
  - Equipment implies buying and maintaining usable tools and machines
  - Organizational issues means CRM etc
- For any Error Type we can have:
  - Significantly over-represented causal factor therefore worth changing
  - Significantly under-represented causal factor, therefore not worth changing

Not just significant factors!

- We have found causal factors significantly over-represented and significantly under-represented for each Error Type
- But some causal factors “not significant”
  - Equipment / tools / parts
  - Airplane design / configuration
  - Knowledge / skills / qualifications
  - Communications
- These imply interventions equally effective across all error types

Issues to watch

- Data quality:
  - Investigators have “favorite” causes
  - When to stop data gathering?
- If you use a data base, the lack of reporting narrative loses “rich” data. Test is: can you reconstruct the incident from data base entry?
- Data & depth of analysis: the deeper you can go the more specific your interventions

LL's: Re-use of Incident Data

- Investigation data: dealing with each specific incident AND using accumulated data to find patterns
- Patterns from cross-tabulation: Error type vs Contributing factor
- Over-represented factors lead to specific interventions with high chance of success
- Some interventions may be equally effective across all error types
- Can re-use existing incident data to predict effectiveness

Let’s do it

How to Abstract

- Read all incidents and
- (1) Classify incidents into categories, e.g. based on outcomes or task elements. Calling these “Hazard Patterns” here
- (2) Classify causal factors using any convenient scheme, e.g. Task, Operator, Machine, Environment, Social (TOMES) or SHELL in aviation

An Example of Abstraction

- Comes from an analysis of 206 aviation maintenance incidents
- Data were collected over time but largely unused
- Each individual incident had been “dealt with” and “solved”

Hazard patterns: overview

1. Aircraft Parked at Hanger or Gate
    - 1.1. Equipment Strikes Aircraft
    - 1.2 A/C or part contacts object
2. Aircraft under tow
    - 2.1. Towing vehicle strikes aircraft
    - 2.2. A/C not configured for towing
    - 2.3. A/C strikes fixed object

Hazard Pattern	Number of Incidents			% of Total
1. **Aircraft is Parked at the Hangar/Gate/Tarmac**	81			**62.3**
1.1 Equipment Strikes Aircraft		51		
1.1.1 Tools/Materials Contact Aircraft			4	
1.1.2 Workstand Contacts Aircraft			23	
1.1.3 Ground Equipment is Driven into Aircraft			13	
1.1.4 Unmanned Equipment Rolls into Aircraft			6	
1.1.5 Hangar Doors Closed Onto Aircraft			5	
1.2 Aircraft (or Aircraft Part) Moves to Contact Object		30		
1.2.1 Position of Aircraft Components Changes			15	
1.2.2 Center of Gravity Shifts			9	
1.2.3 Aircraft Rolls Forward/Backward			6	
2. Aircraft is Being Towed	49			**37.7**
2.1 Towing Vehicle Strikes Aircraft		5		
2.2 Aircraft is Not Properly Configured for Towing		2		
2.3 Aircraft Contacts Fixed Object/Equipment		42		
2.3.1 Aircraft Contacts Fixed Object/Equipment			13	
2.3.2 Aircraft Contacts Moveable Object/Equipment			29	
Totals	130	130	130	100%

Latent Failures: overview

A. Poor communication
B. Poor equipment
C. Incorrect number of personnel
D. Inadequate space
E. Problems with painted guidelines
F. Personnel unaware of concurrent work
G. Pressure for on-time departures
H. Lack of awareness of risk / hazard
I. Pushback policies not enforced

Latent Failure ID	Description of Latent Failure	Number of Incidents
A	**Poor Communication**	**29**
A1	Poor Communication: Between Crew	24
A2	Poor Communication: Between Shifts	5
B	**Poor Equipment**	**72**
B1	Poor Equipment: Inappropriate for Task	39
B2	Poor Equipment: Mechanical Problem	33
C	**Correct Number of Personnel Not Used**	**36**
D	**Inadequate Space**	**30**
D1	Inadequate Space: Congested Area	22
D2	Inadequate Space: Ill-suited for Task	8
E	**Problems With Painted Guide Lines**	**21**
E1	Guide Lines: Do Not Exist	7
E2	Guide Lines: Do Not Extend Out of Hangar	4
E3	Guide Lines: Not Suitable for Aircraft	10
F	**Personnel Unaware of Concurrent Work**	**8**
G	**Pressures to Maintain On-Time Departures**	**19**
H	**Lack of Awareness of Risks/Hazards**	**34**
I	**Pushback Policies Not Enforced**	**16**
	TOTAL	**265**

Cross-Tabulate HP's and CF's

- Get ENORMOUS table!
- Use Chi-Square test to find if HP's and CF's related
- Use Standardized Residuals for finding over-represented cells: focus interventions
- Many cells empty, therefore statistics suspect, but can always combine categories: abstraction again
- (Note: don't combine first, as far more difficult to un-combine later!)

Hazard Patterns x Latent Failures

	A	A1	A2	B	B1	B2	C	D	D1	D2	E	E1	E2	E3	F	G	H	I	Total
1	**17**	**13**	**4**	**53**	**33**	**20**	**22**	**12**	**8**	**4**	**8**	**2**	**1**	**5**	**8**	**11**	**22**	**4**	**157**
1.1	*5*	*2*	*3*	*47*	*30*	*17*	*17*	*11*	*8*	*3*	*7*	*1*	*1*	*5*	*1*	*6*	*10*	*2*	***106***
1.1.1	**3**	1	2	**3**	1	2	**0**	**1**	0	1	**0**	0	0	0	**0**	**0**	**2**	**0**	**9**
1.1.2	**1**	1	0	**29**	25	4	**6**	**0**	0	0	**1**	0	0	1	**1**	**4**	**2**	**1**	**45**
1.1.3	**0**	0	0	**7**	4	3	**9**	**7**	7	0	**1**	0	0	1	**0**	**2**	**0**	**1**	**27**
1.1.4	**0**	0	0	**8**	0	8	**2**	**0**	0	0	**0**	0	0	0	**0**	**0**	**4**	**0**	**14**
1.1.5	**1**	0	1	**0**	0	0	**0**	**3**	1	2	**5**	1	1	3	**0**	**0**	**2**	**0**	**11**
1.2	*12*	*11*	*1*	*6*	*3*	*3*	*5*	*1*	*0*	*1*	*1*	*1*	*0*	*0*	*7*	*5*	*12*	*2*	***51***
1.2.1	**8**	7	1	**1**	1	0	**5**	**0**	0	0	**0**	0	0	0	**2**	**3**	**5**	**0**	**24**
1.2.2	**2**	2	0	**3**	2	1	**0**	**0**	0	0	**1**	1	0	0	**5**	**1**	**5**	**1**	**18**
1.2.3	**2**	2	0	**2**	0	2	**0**	**1**	0	1	**0**	0	0	0	**0**	**1**	**2**	**1**	**9**
2	**12**	**11**	**1**	**19**	**6**	**13**	**14**	**18**	**14**	**4**	**13**	**5**	**3**	**5**	**0**	**8**	**12**	**12**	**108**
2.1	**0**	0	0	**8**	3	5	**2**	**0**	0	0	**0**	0	0	0	**0**	**0**	**3**	**0**	**13**
2.2	**2**	2	0	**0**	0	0	**0**	**0**	0	0	**0**	0	0	0	**0**	**1**	**0**	**1**	**4**
2.3	*10*	*9*	*1*	*11*	*3*	*8*	*12*	*18*	*14*	*4*	*13*	*5*	*3*	*5*	*0*	*7*	*9*	*11*	***91***
2.3.1	**2**	1	1	**4**	1	3	**2**	**8**	4	4	**5**	1	1	3	**0**	**1**	**3**	**4**	**29**
2.3.2	**8**	8	0	**7**	2	5	**10**	**10**	10	0	**8**	4	2	2	**0**	**6**	**6**	**7**	**62**
Total	29	24	5	72	39	33	36	30	22	8	21	7	4	10	8	19	34	16	**265**

Top - level relationship: 1 vs 2

	A/C park	A/C tow
Poor communication	17	12
Poor equipment	**53**	19
Incorrect No. of presonnel	22	14
Inadequate space	12	**18**
Problems with guidelines	8	**13**
Unaware of concurrent wk	**8**	0
On-time pressures	11	8
Lack of hazard awareness	22	12
Push back policies	4	**12**

Next-level relationship: 1.1 vs 1.2

	Eq. strikes	A/C strikes
Poor communication	5	**12**
Poor equipment	**47**	6
Incorrect No. of presonnel	17	5
Inadequate space	11	1
Problems with guidelines	7	1
Unaware of concurrent wk	1	**7**
On-time pressures	6	5
Lack of hazard awareness	10	**12**
Push back policies	2	2

Conclusions: What is Effective

- Aircraft under Tow
  - More space
  - Better guidelines on ground
  - Follow pushback policies
- Aircraft Parked:
  - Better awareness of concurrent work
  - Equipment strikes aircraft:
    - Better equipment
  - Aircraft parts strike equipment
    - Better communication / hazard awareness